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CONNECTOR ASSEMBLY

The present invention relates to connector assemblies for attaching concrete bodies to structures, for example in composite slabs, columns, beams or any structure attached to concrete slabs, blocks, etc.

The present invention also relates to connector elements that can be used as part of the connector assemblies.

The present invention also relates to clips that can be used as part of the connector assemblies.

In one form, the present invention relates to connector assemblies that include connectors in the form of shear connector studs that form the main connection between a frame structure and a concrete slab.

In addition, in one form, the present invention relates to connector elements that can be used with the shear connector studs.

In addition, in one form, the present invention relates to clips that can be used with the shear connector studs and the connector elements.

BACKGROUND TO THE INVENTION

Forming concrete composite structures in building construction involves assembling a structural framework

with cross-connecting primary beams and secondary beams, and laying a ribbed decking across the supporting primary and secondary beams. Reinforcing bars or mesh are then layed on top of the decking. Concrete is poured on top of the decking to complete the composite structure. In construction works the structural framework is usually made of steel. Figure 1 illustrates an example of a steel/concrete composite floor. When the concrete hardens and reaches sufficient compressive strength, the decking provides the main reinforcement for the concrete slab and the slab becomes the top flange of the composite beam.

Connectors in the form of shear connector studs are often used to strengthen the connection between the steel framework and concrete slab. The studs are fixed, generally welded, upright through the steel decking or through a pre-punched hole in the decking before the concrete is poured and are placed above the primary or secondary beams. Once the studs are cast in concrete, they become an important part of the connection formed between the steel framework and concrete slab.

Depending on the profile of the decking and the nature of the studs, the strength, ductility and efficiency of the shear connection formed between the concrete slab and framework can under ultimate load conditions lead to the common problem of rib punch-through failure.

Referring by way of example to steel/concrete composite structures, rib punch-through failure occurs when the studs are subjected to longitudinal shear forces between the concrete and steel framework. The weight of the structure and the load it supports have the effect of thrusting the concrete against one side of each stud creating concentrated stresses at the base of the stud and forming a break-away wedge in the concrete which, under

the longitudinal shear force, is pushed into the ribs of the steel decking and away from the studs. This situation is illustrated in Figure 2A. Arrow A indicates the direction of shear force in the concrete C against the stud S fixed through decking D to steel beam SB. The break-away concrete wedge is denoted by W. With the steel stud no longer confined by concrete around its base, it can be bent relatively easily under the effects of the shearing force. This mode of failure significantly reduces the shear strength of the welded studs, making their shear force/slip behaviour possibly brittle and overall reducing the strength of the composite structure. The likelihood of punch-through failure increases as the number of shear connectors per pan increases and/or as the size of the connector increases.

Ductility is a desirable feature of shear connector studs and in some countries it is mandatory in their national design Standards that the shear connector studs in composite structures be ductile. Ductility can be assessed according to the relationship between the shear force and slip, where the slip occurs longitudinally between the concrete slab and steel beam. The slip is indicated in Figure 2A by Dimension B. The definition of a ductile shear connector stud in some national design standards is one having a characteristic slip capacity exceeding 6 mm. Noting that slip capacity in a solid slab increases with shank diameter, studs with certain dimensions are considered ductile. For example, some national design Standards accept a headed stud as being ductile if the stud has an overall length after welding of at least 4 times the shank diameter, and with a diameter of not less than 16 mm and not exceeding 22 mm.

Areas most prone to cracks and wedges forming in concrete slabs or structures are regions close to edges or voids. Examples of voids include profiled ribbing on

steel decking creating notch-like voids in the concrete body, while hollow cores in pre-cast concrete also create voids. Of the open or closed type variety of steel decking ribs the more significant problems are associated with the open type ribs which are more responsible for creating notch-like voids in the concrete body.

Rib punch-through failure occurs predominantly in secondary beams, that is beams spanning effectively perpendicular to the decking ribs, because with secondary beams the thrust forces are directed across the ribbed decking and are thus more likely to carry the effects of voids in the ribs to the stud shanks between the ribs. The concrete layer in composite slabs is generally in compression whilst the steel beams underneath are in tension. Accordingly, the compressive force in the concrete reduces from the middle of a beam, where the moments are greatest, to the ends of typcially simply supported composite beams where the moments reduce to zero. This describes a composite beam in positive bending, but longitudinal shear forces also develop in the negative moment regions in continuous composite beams which can also lead to rib punch-through failure. In primary beams the phenomenon of rib punch-through failure is less likely because the shear forces run parallel to the decking ribs and therefore the rib voids are less likely to affect the studs between the ribs. This is not to say that rib punch-through failure does not occur in primary beams because even though the shear force runs parallel to the decking ribs, concrete surrounding each stud is still known to be thrust laterally to the decking sheets through the sides of the open ribs. Haunch width of the concrete can be a critical factor in this regard, as can the presence of reinforcing steel.

In taking the above problems into account at the design stage, empirical design formulae have been

developed for determining the design shear capacity of studs used in composite structures. Whilst the formulae can be of guidance for simple constructions, they are relatively inaccurate in practice.

It is thought that placing studs in pairs improves the strength of the shear connection, however quite the opposite can be found to be true with strength and ductility actually reduced due to rib punch-through failure.

The above problems are not exclusive to concrete composite beams but are also found in structures where a component is attached to a concrete body through bolts or fasteners embedded in the concrete body. The connected structure may be a pole, beam, leg of a larger structure, or the like. Figure 2B illustrates such a situation where two bolts B cast in a concrete slab C connect a structural component SC to the concrete slab through a plate P to which the bolts are connected with nuts N. With the upper shear force travelling in the direction of Arrow A, a cracked wedge W is likely to form at the free edge FE of the concrete slab. The free edge has a similar effect on the casting-bolts as the voids in the composite beam examples given above, that is, the free edge is a point of weakness in the concrete where a crack may form. If a connecting bolt is located close to the free edge illustrated in Figure 2B, a wedge of concrete breaking off at the free edge could weaken or dislodge concrete around the embedded bolt and weaken the bolt's hold in the concrete. The resulting problem is equivalent to rib punch-through failure in composite beams.

A solution is needed to maintain the integrity and strength of composite concrete structures and overcome the adverse effects resulting from the formation of cracks and wedges in concrete composite structures.

SUMMARY OF THE INVENTION

According to the present invention there is provided a connector assembly for connecting together a structural component and a concrete body wherein the connector assembly is capable of resisting shear forces between the structural component and the concrete body and includes:

(a) a connector having a shank with one end adapted to be embedded in concrete and the other end adapted to be attached to the structural component; and

(b) a connector element that is adapted to surround the connector and form a barrier that is spaced from the connector and confines concrete around the connector.

Preferably the connector assembly includes a means for holding the connector element around the connector.

Preferably the holding means is a clip extending between the connector and the connector element.

Preferably the connector has a shank with one end adapted to be embedded in concrete and the other end adapted to be attached to the structural component.

With such an arrangement preferably the clip includes:

(a) a means for coupling the clip to a section of the connector element, and

(b) a plurality of legs formed from resilient

material that extend inwardly and have inner ends that describe an opening that can receive the shank of the connector, and which opening has a diameter that is less than that of the shank, whereby in use the legs deflect when the clip is pushed over the shank so that the shank extends through the opening and the inner ends of the legs contact the shank and thereby couple the clip to the shank.

Preferably the holding means is adapted to hold the connector element from the connector so that there is a spacing of at least 20 mm between the components.

More preferably the holding means is adapted to hold the connector element from the connector a spacing of at least 25 mm.

More preferably the holding means is adapted to hold the connector element from the connector so that there is a spacing of at least 30 mm.

Preferably the holding means is adapted to hold the connector element from the connector so that there is a spacing of at least the maximum size of aggregate in concrete in the concrete body between the components.

More preferably the holding means is adapted to hold the connector element from the connector so that there is a spacing of least 1.25 times the maximum size of aggregate in concrete in the concrete body.

More preferably the holding means is adapted to hold the connector element from the connector so that there is a spacing of at least 1.5 times the maximum size of aggregate in concrete in the concrete body.

The connector element may be, by way of example,

a ring of solid material, specifically galvanised steel, a ring of mesh or a coil with small pitch windings.

In a situation where the connector element is a coil with small pitch windings, preferably the ends of the coils are closed to facilitate the development of hoop stresses in the coil.

Preferably the connector element is a continuous ring of solid material, such as steel.

In the embodiment of the solid steel ring connector element, preferably at least the rings are cut from a length of galvanised steel tube. The rings preferably have an outer diameter of 76 mm and a wall 2 mm thick. High tensile steel of 350 MPa proof stress is preferred over lower grade steel. The connector element is preferably kept centrally in position before the concrete is poured with a restraining clip that defines the means for holding the connector element around the connector.

In a situation in which the concrete body is supported by a profiled decking having an upstanding rib or ribs separated by pans, preferably the connector element is annular and preferably has a height approximately 60% - 80% the height of the rib or ribs on the decking and ideally 70% the height of the rib or ribs.

The connector element is preferably provided with lateral cross plates on opposite sides of the element wherein the cross plates are adapted to support reinforcing rods extending parallel to the decking ribs to assist in confining the concrete around the connector.

According to the present invention there is further provided a composite concrete structure including

a concrete body and a structural component connected together by way of a connector assembly, the connector assembly including:

(a) a connector embedded in concrete and attached to the structural component; and

(b) a connector element that surrounds the connector and forms a barrier that is spaced from the connector and confines concrete around the connector.

Preferably the connector assembly includes a means holding the connector element around the connector.

Preferably the holding means is a clip extending between the connector and the connector element.

Preferably the spacing of the connector element from the connector is at least 20 mm.

More preferably the spacing of the connector element from the connector is at least 25 mm.

More preferably the spacing of the connector element from the connector is at least 30 mm.

Preferably the spacing of the connector element from the connector is at least the maximum size of aggregate in concrete in the concrete body.

More preferably the spacing of the connector element from the connector is at least 1.25 times the maximum size of aggregate in concrete in the concrete body.

More preferably the spacing of the connector element from the connector is at least 1.5 times the

maximum size of aggregate in concrete in the concrete body.

In one embodiment, the connector element may surround more than one connector.

According to the present invention there is still further provided a shear connector assembly for use in construction of concrete composite structures having a concrete body supported by a decking on a structural framework, the shear connector assembly including:

(a) at least one shear connector stud adapted to be permanently fixed through the decking; and

(b) a connector element adapted to form a barrier surrounding at least one connector stud a spaced distance therefrom to confine the concrete around the connector stud.

Preferably the shear connector assembly includes a means for holding the connector element around the connector stud and concentric of the stud.

Preferably the holding means is a clip extending between the connector and the connector element.

According to the present invention there is still further provided a method of forming a composite concrete structure including:

(a) assembling a structural frame incorporating interconnected cross-beams and a decking mounted on the beams;

(b) permanently fixing shear connector studs upright through the decking and aligned with the beams;

(c) positioning a connector element in relation to the decking wherein the element forms a barrier surrounding at least one stud a spaced distance therefrom; and

(d) pouring concrete on the decking to form a composite structure.

Ideally, the method includes cutting more than one connector element from a length of steel tube.

The method further includes distancing the stud and surrounding connector element from the decking rib at which concrete failure is most likely to occur.

According to the present invention there is further provided a clip for use with the above-described connector assembly.

The purpose of the clip is to facilitate locating the connector element in relation to the connector. This is a particularly important issue in the difficult working environment in which the connector assembly is generally used.

In general terms, the clip includes:

(a) a means for coupling the clip to a section of the connector element, and

(b) a plurality of legs formed from resilient material that extend inwardly and have inner ends that describe an opening that can receive a section of the connector, and which opening has a diameter that is less than that of the connector section, whereby in use the legs deflect when the clip is pushed over the connector so

that the connector section extends through the opening and the inner ends of the legs contact the connector section and thereby couple the clip to the connector.

The above described clip makes it possible to effectively lock the clip and thereby the connector element to the connector.

Preferably the legs are formed to enable the legs to flex in at least one direction, when in use the clip is pushed over the connector to locate the clip on the connector.

Preferably the legs are formed to enable the legs to flex in two mutually perpendicular directions, when in use the clip is pushed over the connector to locate the clip on the connector.

Preferably at least one of the legs includes an upward crank.

The cranked end facilitates guiding the clip onto the connector.

In addition, the cranked end facilitates initially locating the clip in the correct orientation in relation to the connector section. Specifically, the cranked end provides an obvious visual indication of the correct orientation of the clip in relation to the connector section.

In addition, the cranked end increases resistance to sliding movement of the clip after it has been located on the connector section. Specifically, sliding movement tends to cause the upwardly cranked end or ends to dig into the connector section and thereby increase resistance to further sliding movement.

Preferably the leg or legs that include the cranked end further include a leg section that is formed to increase the flexibility of the leg.

The leg section reduces the force required to push the clip over the connector to locate the clip on the connector section and makes it possible to control the bending stresses in the legs, thereby preventing yielding of the legs. Yielding of the legs is unsatisfactory because it prevents good engagement of the clip onto the connector.

Preferably the leg section is in the form of a curved bend in the leg outwardly of the cranked end.

Preferably the inner ends of the legs are relatively wide to enable the legs to grip the connector section securely.

Preferably the inner ends of the legs include projections that enable the legs to grip the connector section securely.

Preferably the legs are formed from spring steel.

Preferably the legs are formed so as to minimise interference to concrete flowing into the volume defined by the connector element that enclose the connector.

Preferably the means for coupling the clip to the section of the connector element includes a plurality of clasps that can clip onto the upper section of the connector element.

The applicant has realised that it is possible to integrally form the above-described connector element and

clip as a connector element assembly and that considerable advantages can be achieved with this combination.

Accordingly, the present invention also provides a connector element assembly for use in a connector assembly for connecting together a concrete body and a structural component wherein the connector assembly is capable of resisting shear forces between the structural component and the concrete body.

The connector assembly includes the connector element assembly and a connector adapted to be embedded in concrete.

The connector element assembly of the present invention includes:

(a) a barrier section to confine concrete around the connector, and

(b) an integrally formed clip section for coupling the connector element, and more particularly the barrier section, to the connector.

Preferably the clip section includes a plurality of legs formed from resilient material that extend inwardly from an upper section of the barrier section and have inner ends that describe an opening that can receive a section of the connector and have a diameter that is less than that of the connector section, whereby in use the legs deflect when the connector element is pushed over the shank so that the shank extends through the opening and the inner ends of the legs contact the connector section and thereby couple the connector element to the connector with the barrier section positioned to surround the connector.

The above-described connector element assembly can be effectively locked to the connector. The connector element assembly can be located on a connector after the connector has been secured, for example by welding, to a structural component. Alternatively, the connector element assembly can be located on a connector before the connector is secured, for example by welding, to a structural component.

The connector may be any suitable form of fastener having a shank with one end adapted to be embedded in concrete. For example, the connector may be a headed stud or a structural bolt.

The headed stud may be a two component construction, with a headed member and a shank member that have complementary screw-threaded sections that facilitate connecting the members together. This arrangement facilitates locating the connector element assembly on the connector. Specifically, with this arrangement, the connector element assembly can be conveniently located on the shank member when the shank member is disconnected from the headed member by sliding the assembly along the length of the shank member and thereafter connecting the headed member to the shank member.

Preferably the legs are formed so that the legs can flex in one direction, when in use the connector element is pushed over the connector to locate the connector element on the connector.

Preferably the legs are formed so that the legs can flex in two mutually perpendicular directions, when in use the connector element is pushed downwardly over the shank to locate the connector element on the connector.

Preferably at least one of the legs includes an

upward crank.

The cranked end facilitates guiding the connector element onto the connector.

In addition, the cranked end facilitates initially locating the connector element in the correct orientation in relation to the connector section. Specifically, the cranked end provides an obvious visual indication of the correct orientation of the connector element, and more particularly the clip section of the connector element, in relation to the connector section.

In addition, the cranked end increases resistance to sliding movement of the connector element after it has been located on the connector section. Specifically, sliding movement tends to cause the upwardly cranked end or ends to dig into the connector section and thereby increase resistance to further sliding movement.

Preferably the leg or legs that include the cranked end further include a first leg section that is formed to increase the flexibility of the leg.

The first leg section reduces the downward force required to push the connector element over the connector to locate the connector element on the connector section and makes it possible to control the bending stresses in the legs, thereby preventing yielding of the legs. Yielding of the legs is unsatisfactory because it prevents good engagement of the connector element, and more particularly the clip section of the connector element, onto the connector.

Preferably the leg section is in the form of a curved bend in the leg outwardly of the cranked end.

Preferably the inner ends of the legs are relatively wide to enable the legs to grip the connector section securely.

Preferably the inner ends of the legs include projections that enable the legs to grip the shank securely.

Preferably the legs are formed from spring steel.

Preferably the legs are formed so as to minimise interference to concrete flowing into the volume defined by the connector element that enclose the connector.

Preferably the opening is a circular opening.

According to the present invention there is also provided a method of manufacturing the above-described connector element assembly that includes stamping a flat blank from a steel sheet, the blank having (a) a rectangular section that corresponds to the barrier section and (b) 4 elongate members extending from one side of the rectangle that correspond to the legs of the clip section, folding the rectangular section of the blank to form the barrier section, and shaping the elongate members to form the legs of the clip section.

According to the present invention there is also provided a method of manufacturing the above-described connector element assembly that includes pressing a cup-shaped member from a steel sheet, the cup-shaped member having a cylindrical wall that forms the barrier section, and stamping the base to form the legs of the clip section.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described further by way of example with reference to the accompanying drawings by which:

Figure 1 illustrates a conventional composite structure in a building construction;

Figure 2A is an illustration showing the problems associated with the prior art composite beams;

Figure 2B illustrates problems associated with another prior art composite structure;

Figure 3 is a perspective view of a connector assembly according to an embodiment of the present invention;

Figure 4 is a side sectional view of the connector assembly shown in Figure 3;

Figure 5 is another side sectional view of the connector assembly shown in Figure 3;

Figure 6 is a side view of an embodiment of a connector assembly in accordance with the invention incorporating a restraining clip;

Figure 7 is a sectional plan view of Figure 6 taken along line 7-7;

Figure 8 is a perspective view of the connector assembly shown in Figure 3 with reinforcing rods;

Figure 9 is a graph showing results of a first test involving prior art;

Figure 10 is a graph showing results of the same test as Figure 9 but incorporating the present invention;

Figure 11 is a graph showing results from a second test involving the present invention;

Figure 12 is a vertical cross-section through an embodiment of a clip in accordance with the present invention coupled to a connector element;

Figure 13 is a top plan view of the clip and the connector element shown in Figure 12;

Figure 14 is a vertical cross-section through an embodiment of a connector element assembly in accordance with the present invention, the Figure also showing in outline a connector and illustrating the position of the connector element assembly in relation to the connector in use of these components as a connector assembly; and

Figure 15 is a top plan view of the connector element shown in Figure 14.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

A connector assembly illustrated in the Figures includes shear connector element 10 and a connector in the form of a fastener that connects the components of a concrete composite structure. The connector element increases the ductility and shear strength, and therefore the shear resistance, of a fastener in a concrete

composite structure by surrounding the fastener in the form of a barrier thereby confining the concrete around the fastener. In a preferred embodiment, which is the main embodiment described herein, the connector element surrounds a connector in the form of a stud that is mounted upright on decking in a composite concrete beam. However, it is understood that the present connector assembly could apply to any composite structure involving the connection of a component to concrete using connectors embedded in the concrete.

Figure 3 illustrates a standard shear connector stud 11 welded through ribbed decking 12, either directly or through a pre-punched hole, to a secondary steel beam 13. A shear connector element 10 surrounds stud 11. Figure 4 is a side sectional view of Figure 3 but with the stud 11 and element 10 embedded in a bed of concrete 14. The shear connector element 10 sits on the pan 22 of the decking and forms a barrier surrounding the stud. More specifically, the barrier surrounds the base of the stud shank. In the preferred embodiment the decking is a steel ribbed decking, either directly or through a pre-punched hole, and the stud is welded through the decking to the steel beam underneath.

When concrete is poured onto the decking to cover the stud 11 and element 10 it flows into a pocket 15 defined by the area enclosed by the element 10 and totally embeds both the stud and element in concrete. Placing the barrier element 10 around the stud 11 has the effect of confining the concrete around the base of the stud and preventing concrete from escaping the element confines. Accordingly, the base of the stud is securely confined

regardless of the formation of cracks or wedges that would otherwise dislodge concrete from around the stud base.

In the embodiment shown, the connector element 10 is an annular steel ring spaced approximately 38 mm from the axial centre of the stud. However, the element 10 need not be a solid annular barrier but can be an element forming a barrier with other characteristics and shapes. For example, the element may be an annular mesh or grid element surrounding the stud which, while still effective in confining the concrete around the base of the stud, also provides the wet concrete access to the pocket 15 to more quickly and thoroughly fill the pocket by allowing the wet concrete to flow through the holes in the mesh barrier. Similarly, the element could consist of a spiral coil surrounding the stud and having windings of a sufficiently small pitch so as to provide a confining barrier but still allow concrete to flow in between the windings. Elements made of steel are convenient, economical and relatively simple to use, however elements made of other materials capable of forming suitable barriers are also envisaged. For example, other materials that could be used are high-strength plastic or composite materials that do not chemically react with the concrete. In the preferred embodiment the elements are steel rings, that are cut from a length of steel tubing.

In the embodiment illustrated in Figure 5 the base of the annular ring element is cut to accommodate interconnection lips or joints. Similarly, the element can be modified to accommodate other features of the decking such as low ribs.

To keep the elements centrally in position before the concrete is poured, a holding or restraining clip 30 illustrated in Figures 6 and 7 is located on the top rim 21 of the element 10. The restraining clip is similar in principle to a circlip but instead has three arms 31 substantially equally separated from each other extending outwardly from a semi-circular centre 32. Centre 32 clips around the shank 16 of stud 11 and the three arms 31 extend towards the top rim 21 of the connector element 10 and clip onto the rim 21 by way of clasps 33 at the end of each arm 31. The retaining clip is resilient such that the arms 31 are able to maintain the connector element 10 a spaced distance from the stud 11 but allow some amount of flexibility to enable the components to be assembled and to withstand the forces of the moving wet concrete during casting. In an alternate embodiment, the restraining clip only has two opposed arms extending from a semi-circular centre. The clip is likely to be made of a resilient plastic. As illustrated in Figure 6 the circular centre 32 of the clip 30 is placed higher on the stud shank 16 than the top of the element 10 with the arms extending downwardly onto the rim 21 to in effect hold the element 10 down so that it does not displace during pouring of concrete. It is understood that the retaining clip is not the only means of holding the element around the stud and that any mechanical equivalent could work equally as well to maintain the element in the correct position before and during casting. A further embodiment of the holding means is described in relation to Figures 12 and 13.

Bursting stresses develop in the concrete at studs or fasteners under high shear force that can cause a

vertical splitting crack to form between the stud and the void, that is, the crack forms perpendicular to the void 26 shown in Figure 4. This may occur before the formation of a wedge in the concrete as shown in Figure 4. Therefore, placing a reinforcing bar across the crack caused by the bursting stresses assists in resisting formation of a wedge. Figure 8 illustrates two reinforcing rods 35 held parallel to ribs 20 on decking 12 by cross plates 36 attached laterally to connector element 10 on opposing sides of the element. Figure 4 illustrates the rods in cross-section. Cross plates 36 are welded to the connector element and contain apertures 37 through which the reinforcing rods 35 extend and are held in place. The orientation of the reinforcing rods 35 is such that when embedded in concrete they traverse a bursted seam that may form and by extending into more solid concrete the rods anchor the concrete around the stud 11. Maximum effect is achieved by placing the rods deep into where the wedge will form and reasonably close to the web 23 of the rib.

The reinforcing rods are one way of assisting to increase the holding strength of the present connector assembly. Additionally, the head 17 of the stud 11 should be fully embedded in the concrete cover slab above the decking ribs. The relative height of the stud 11 to the top of the decking ribs 20 also affects the strength of the connector assembly. It has been found that a stud having a height of at least 40 mm above the top of the ribs 20 has improved its performance. Furthermore, increasing the height of the element 10 to the height of the rib can improve the performance to that of a shear connector in a solid slab without voids.

Stud performance was tested using studs having a height of 95 mm welded through steel ribbed decking with ribs having a height of 55 mm. Figure 4 illustrates the set up of a first test with and without an element 10. In the first test a connector element 10 having a height of 40 mm and clipped to the stud 11 was found to perform satisfactorily in confining the concrete around the base of the stud. Accordingly, an element height of at least 70% of the height of decking ribs 20 will sufficiently confine the concrete and prevent wedges or cracks entering the pocket 15 from above the top rim 21 of the element 10. As mentioned above, an even better performance is achieved where the height of the element equals or exceeds that of the ribs. Whilst an element height of 20 mm was found to offer some improvement, it did not perform as well as the 40 mm high element tested. Logically the higher the element forming the barrier up to a height reaching the height of the rib, the better the performance of the stud. The steel ring of the tested element had an outer diameter of 76 mm and a wall thickness of 2 mm.

Sometimes multiple studs are placed adjacent to each other on the decking pan 22 to provide increased connection strength. In this case separate elements 10 may be used to surround each stud or, alternatively, a single element having a rectangular, oval, or the like, shape is positioned to surround both studs. Inner dividing walls of the element in these situations may be provided to compartmentalise the element giving each stud its own pocket of locally confined concrete. Hence, when the concrete is poured it flows into all pockets of the element surrounding the studs. The element prevents

cracks and wedges from forming inside the walls of the element.

Tests performed on the single mounted stud and decking assembly illustrated in Figure 4 were performed without and with the barrier element 10 and the results are illustrated in Figures 9 and 10 respectively. The shear force acting on the stud was plotted against the stud slip as defined in Figure 2. The results provide an indication of the ductility of the stud and hence its performance to resist shear force. In Figure 4 the top shear force travels in the direction of Arrow SF.

Figure 9 illustrates the results of the single mounted stud welded to the decking substantially equidistant from the webs 23 of the decking ribs 20, illustrated in Figure 4 but without the connector element 10 or bars 35. The graph of Figure 9 shows that at the standard 6 mm slip the shear force on the stud was approximately 53 kN. Another important point is that there is a substantial drop off of load below the peak level at a slip of approximately 2mm and in accordance with some standards the behaviour is brittle and therefore unsatisfactory.

In contrast, the same arrangement but with a circumventing connector element was tested and the results are shown in the graph of Figure 10. The shear force at the 6 mm slip mark was remarkably higher at 81 kN, almost a 53% improvement on the stud without the element. In addition, the graph indicates that there is no substantial drop off of load after the peak load, thereby indicating that the behaviour is ductile and therefore satisfactory.

The element used in the above tests was 40 mm in height and surrounded a 95 mm high stud with its centre located 68 mm from the base of the rib web 23 at which a wedge would form. The stud was welded equidistant between the right-side rib 25 and left-side rib 24, which calculates to be 68 mm from the base of the web of the right-side rib 25.

It has been found that shear strength of studs significantly improves if the distance of the studs to the active rib webs 23 are increased. For example, Figure 5 illustrates a stud located closer to the left-side rib 24 than the right-side rib 25. With the top shear force travelling in the direction of Arrow SF a wedge is likely to form at the right-side rib 25. Hence, moving the stud further away from this rib 25 increases the size of the wedge of concrete that has to be dislodged around the base of a stud. Combining the increased distance between the stud and active rib with the use of the present connector element can significantly increase the shear strength and ductility of the stud. The graph of Figure 11 shows the results of a shear force verses slip test of a stud located 100 mm away from the right-side rib 25 as illustrated in Figure 5. The stud is surrounded by a connector element 40 mm in height. The graph results show that at the 6 mm slip mark the stud sustained a force of approximately 115 kN and finally fractured just under 120 kN, which is an extremely favourable performance as if the stud had been in a solid concrete slab without voids.

However, this optimal performance is also achievable with a higher connector element 10 or a higher

stud 11 and with the stud closer to the rib.

It is noted that all of the examples and tests described herein involve longitudinal shear force in secondary composite beams, which sustain the most damage, where the beams are in positive bending. However, it is noted that failure is also likely in secondary composite beams where longitudinal forces develop in regions of negative moments.

The advantage of placing the present connector element around the stud to form a connector assembly and encapsulate and localise concrete at the stud base, as shown in Figures 3 and 4, produces significant and important increases in strength and ductility of the studs, and on the whole make them more robust. This in turn translates to a composite structure where the major problem of rib punch-through failure is significantly reduced or entirely avoided. Additionally, the number of connector assemblies required in composite structures can be reduced on account of the increased strength which leads to shorter installation time and less material. With the present connector assembly the composite concrete structure is able to withstand a much higher ultimate load and, with its increased structural integrity, provide a more reliable and more economical construction.

Figures 12 and 13 illustrate an embodiment of a clip for holding a connector element 3 in relation to a connector.

The connector element 3 shown in Figure 12 forms part of a connector assembly of the type disclosed in

Figures 3 and 4.

The connector element 3 is in the form of a steel ring that has an upper rim 5.

Whilst not shown, the connector assembly also includes a connector in the form of a fastener that has a shank and an enlarged head that connects a component such as a steel column to an underlying foundation prior to pouring concrete into the foundation. In this application the connector element 3 increases the ductility and shear strength, and therefore the shear resistance, of the fastener by forming a barrier around the connector and thereby confining concrete around the fastener.

The purpose of the clip, generally identified by the numeral 7, in Figures 12 and 13 is to facilitate locating the connector element 3 securely in place in relation to the connector before concrete is poured. In order to achieve this objective, the clip 7 is located first on the connector element 3 and the assembly of the connector element 3 and the clip 7 are located on the shank by positioning the clip above the shank and then pushing the clip down onto the shank.

The clip 3 includes a circular outer frame 9. The frame 9 includes an inner circular wall 11 that has a diameter that enables the wall to contact an inner surface of the connector element 3 when the clip 7 is coupled to the connector element 3. The wall provides stability to the assembly of the connector element 3 and the clip 7.

The clip 3 shown in Figures 12 and 13 also

includes 2 pairs of outer clasps 13 that can be located over the rim 5 of the connector element 3 and couple the clip 7 securely to the connector element 3.

The clip 7 also includes 4 equally spaced legs 15 extending inwardly from the frame 9.

The legs 15 are formed from spring steel. The legs 15 terminate in inner ends 17 that describe a circular opening 19 for receiving the shank of the connector. As described above, the diameter of the described opening 19 is selected to be less that that of the shank so that the legs 15 engage and thereby couple the clip to the connector when the clip is pushed down onto the shank.

The legs include upwardly inclined sections 21 that define a frusto-conical region around the shank. As is described above, these upwardly cranked sections provide a number of advantages, including facilitating guiding the clip onto the shank, facilitating initially locating the clip in the correct orientation in relation to the shank, and increasing resistance to upward movement of the clip after it has been located on the shank.

The connector element assembly shown in Figures 14 and 15 is intended for use as part of a connector assembly of the type shown in Figures 3 and 4 for connecting a component such as a steel column to an underlying foundation prior to pouring concrete into the foundation. In addition to the connector element assembly, the connector assembly also includes a connector 4 (partly shown in outline in Figure 14) in the form of a fastener that has a shank (as shown in the Figure) and an enlarged head at the top (not shown). In this application

the purpose of the connector element assembly is to increase the ductility and shear strength, and therefore the shear resistance, of the connector 4 by forming a barrier around and thereby confining concrete around the connector 4.

The connector element assembly shown in Figures 14 and 15 includes (a) a barrier section 5 and (b) a clip section generally identified by the numeral 7.

The purpose of the barrier section 5 is to confine concrete around the connector 4.

The purpose of the clip section 7 is to facilitate locating the connector element assembly securely in place in relation to the connector 4 before concrete is poured.

The barrier section 5 is in the form of a cylinder or ring.

The clip section 7 includes 4 equally spaced legs 15 extending inwardly from the barrier section 5.

The legs 15 terminate in inner ends 17 that describe a circular opening 19 for receiving the shank of the connector. The diameter of the described opening 19 is selected to be less that that of the shank so that the legs 15 can engage and thereby couple the connector element assembly to the connector 4 when the connector element assembly is positioned onto the shank as shown in Figure 14.

The legs 15 include upwardly inclined sections 21 that define a frusto-conical region around the shank. As is described above, these upwardly cranked sections provide a number of advantages, including facilitating

guiding the connector element assembly onto the shank, facilitating initially locating the connector element assembly in the correct orientation in relation to the shank, and increasing resistance to upward movement of the connector element assembly after it has been located on the shank.

The legs 15 also include a downwardly-curved bend 25 between the frusto-conical region and the junction of the legs 15 and the barrier section 5. The bends 25 increase the effective length of the legs 15.

In use, the connector element assembly is located on the shank of the connector 4 by positioning the clip section 7 above the shank with the legs 21 contacting the head (not shown) of the shank and then pushing the connector element assembly down onto the shank.

One option for manufacturing the connector element assembly is to form the connector element assembly from one piece of flat steel sheet. The first step is to stamp a flat blank from the steel sheet, with the blank having (a) a rectangular section (that corresponds to the barrier section 5), and (b) 4 elongate members extending from one side of the rectangle (that correspond to the legs 15 of the clip section 7). The next step is to roll the rectangular section into a cylinder and to join the ends of the rectangle together. The ends could be joined together by means of hook elements 23 formed at one end that are either passed through openings (not shown) formed at the other end of the rectangle and are then folded back onto the cylinder or by double folding the ends onto each other which has the advantage of not reducing the steel section. Another, although not the only other, option is to weld the ends together. The final step is to shape the legs 15 into the required configuration, as shown in Figure 14.

Another option for manufacturing the connector element assembly is to press a cup having a base and a cylindrical wall from one piece of flat steel sheet, thereafter stamp the base to form an outline of the legs, and finally shape the legs to the form shown in Figure 14.

In both of the above-described options, the formed connected elements are heat treated to form high-tensile spring steel.

It will be understood by a person skilled in the art of the present invention that many modifications may be made without departing from the spirit and scope of the present invention.

By way of example, whilst the embodiments shown in Figures 12 to 15 include 4 legs, the present invention is not so limited and extends to clips and connector elements that have any suitable number of legs.

In addition, whilst the embodiments shown in Figures 12 to 15 include radially extending legs, the present invention is not so limited and extends to legs that are not radial legs.

In addition, whilst the embodiments shown in Figures 12 to 15 include upwardly inclined sections that define a frusto-conical region around the shank, the present invention is not so limited.

In addition, whilst the embodiments shown in the Figures are described in the context of composite concrete structure that includes a decking sheet and a layer of concrete on the sheet and connecting the composite concrete structure to an underlying structural component, the present invention is not so limited and extends to

concrete structures generally. For example, the present invention extends to connector assemblies that can be used in relation to concrete footings and the like that are used to support steel columns with base plates and other structural components. These arrangements typically include connectors in the form of bolts that are embedded in concrete footings and extend from the footings and provide connection points for base plates. In such arrangements, with reference to Figure 2B, the connector assemblies would be fitted upside down underneath the steel base plate on bolts nearest the free edge.

Whilst the embodiments shown in the drawings relate to arrangements in which the connectors extend vertically in use from an underlying support structure, the present invention is not so limited and extends to other arrangements, for example, arrangements in which the connectors extend horizontally in a concrete body. One specific example of such arrangements includes connectors in the form of headed studs that are welded to an upstanding web of a T-section support structure at spaced intervals along the length of the web and extend horizontally into a concrete body. With this particular arrangement, the connector elements are positioned around the horiztonally extending studs.

Whilst the embodiments shown in the drawings relate to arrangements in which the connector elements contact decking sheets, the present invention is not so limited and extends to arrangements in which the connector elements are spaced above decking sheets and thereby allow wet concrete to flow in the gap between the decking sheets and the connector elements.

Furthermore, whilst the discussion of the present invention focuses on applied loads in a particular direction, the present invention is equally applicable to arrangements that are subjected to varying loads in one or more directions.